THE PLANT DISEASE REPORTER

RECD
LIBRARY
SEP 24 1937
BUREAU
OF
PLANT INDUSTRY

Issued By

Division of Mycology and Disease Survey

Supplement 102

Proceedings of the Root-knot Nematode Conference

September 1, 1937.

BUREAU OF PLANT INDUSTRY

UNITED STATES DEPARTMENT OF AGRICULTURE

PROCEEDINGS OF THE ROOT-KNOT NEMATODE CONFERENCE

Held at Nashville, Tennessee, Feb. 2 and 3, 1937

Edited by
H. P. Barss, U. S. Department of Agriculture, S. A. Wingard, Virginia Agricultural Experiment Station, and E. M. Buhrer, G. Steiner, and J. Tyler, U.S. Department of Agriculture.

Plant Disease Reporter
Supplement 102 September 1, 1937.

Table of Contents

ORGANIZATION OF CONFERENCE
LIST OF THOSE PRESENT 98
THE CALLING OF THE CONFERENCE 99
DECISIONS OF THE CONFERENCE 100

DIGEST OF THE CONFERENCE PROGRAM
GENERAL FACTS ABOUT THE ROOT-KNOT NEMATODE, Heterodera marioni . 101
HOST PLANTS 102
ARTIFICIAL CULTURE METHODS 105
PARASITES AND OTHER ENEMIES OF THE ROOT-KNOT NEMATODE 105
RESPONSES TO ENVIRONMENT 106
Temperature
Moisture
Physical and chemical factors
Food supply
METHODS OF DETERMINING AND MEASURING INFESTATIONS. 108
MEANS OF DISSEMINATION. 108
RELATION TO TEMPERATURES IN FLORIDA 109
EXPERIMENTS ON NEMATODE CONTROL IN FLORIDA WITH FERTILIZERS AND CHEMICALS AND BY CULTURAL METHODS 111
CHEMICAL CONTROL STUDIES 113
GENERAL DISCUSSION ON CROP ROTATION WITH RESISTANT PLANTS . . . 114
DEVELOPMENT OF ROOT-KNOT-RESISTANT VARIETIES OF CROP PLANTS . . 115
ELIMINATION OF ROOT-KNOT INFESTATION FROM PLANTS 117
SPECIAL DISCUSSION OF NEMATODE HOSTS 118
THE ROOT-KNOT NEMATODE IN RELATION TO OTHER PLANT PARASITES . . 119

SOME OBJECTIVES IN THE ROOT-KNOT NEMATODE PROGRAM
ROOT-KNOT NEMATODE SURVEY. 119
SUGGESTED LINES FOR INVESTIGATION 120
HOW TO INCREASE EFFECTIVENESS OF ATTACK ON THE PROBLEM 121
ORGANIZATION 122

ORGANIZATION OF CONFERENCE

The first session of the conference was called to order by Chairman R. F. Poole.

LIST OF THOSE PRESENT:

G. M. Armstrong	South Carolina Experiment Station
C. H. Arndt	South Carolina Experiment Station
H. D. Barker	U.S.D.A., Washington, D. C.
H. P. Barss	U.S.D.A., Washington, D. C.
H. W. Barre	U.S.D.A., Washington, D. C.
K. C. Barrons	Alabama Experiment Station
A. N. Brooks	Box 522, Lakeland, Florida.
E. M. Buhrer	U.S.D.A., Washington, D. C.
E. M. Cralley	Arkansas Experiment Station
A. W. Drinkard	Virginia Experiment Station
H. A. Edson	U.S.D.A., Washington, D. C.
I. L. Forbes	Louisiana Experiment Station
U. R. Gore	Georgia Experiment Station
J. E. Hite	U.S.D.A., Jackson, Mississippi
H. H. Hume	Florida Experiment Station
P. H. Kime	U.S.D.A., Raleigh, North Carolina
C. J. King	U.S.D.A., Sacaton, Arizona
R. A. McGinty	South Carolina Experiment Station
H. C. McNamara	U.S.D.A., Greenville, Texas
L. E. Miles	Mississippi Experiment Station
P. R. Miller	U.S.D.A., Washington, D. C.
R. H. Milton	University of Tennessee, Extension Service, Nashville, Tennessee
W. D. Moore	U.S.D.A., Tifton, Georgia
E. G. Moss	Tobacco Station, Oxford, North Carolina
D. C. Neal	U.S.D.A., Baton Rouge, Louisiana
A. G. Plakidas	Louisiana Experiment Station
R. F. Poole	North Carolina Experiment Station
O. A. Pope	U.S.D.A., Washington, D. C.
L. Shaw	North Carolina State College
C. D. Sherbakoff	Tennessee Experiment Station
D. M. Simpson	U.S.D.A., Knoxville, Tennessee
A. L. Smith	Georgia Experiment Station
G. Steiner	U.S.D.A., Washington, D. C.
J. J. Taubenhaus	Texas Experiment Station
A. L. Taylor	U.S.D.A., Tifton, Georgia
W. H. Tharp	Fayetteville, Arkansas.
H. B. Tisdale	Alabama Experiment Station
G. R. Townsend	Florida Everglades Experiment Station
J. Tyler	U.S.D.A., Washington, D. C.

J. O. Ware	U.S.D.A., Washington, D. C.
J. B. Watson	Florida Experiment Station
G. F. Weber	Florida Experiment Station
S. A. Wingard	Virginia Experiment Station
R. Y. Winters	North Carolina Experiment Station

THE CALLING OF THE CONFERENCE. At the beginning of the session Dr. S. A. Wingard, Chairman of the Tobacco Disease Council, was asked to explain how the conference came to be called. He showed that it was the outgrowth of the active interest taken in the nematode problem by the Tobacco Disease Council ever since its formation at Greensboro, North Carolina, in November, 1935. This interest had led the Council at its meeting in Tifton, Georgia, in June, 1936, to pass a resolution suggesting the initiation of a regional nematode survey to be participated in by the state experiment stations interested in the problem, with the hope of cooperation from the Tennessee Valley Authority. This matter was brought before a conference of southeastern experiment station directors later in the summer, but because of some doubt as to the practical value and feasibility of such a survey, the matter was referred back to the Council with an expression of the interest of the directors in the root-knot problem and their request that further consideration be given to the best way of approaching the problem of a more effective regional research program aimed at more effective prevention of nematode damage. The executive committee of the Council then met at Atlantic City, December 30, 1936, during the annual meeting of the American Phytopathological Society, and after thorough discussion decided to call those interested in the root-knot nematode problem to a general conference at Nashville, Tennessee, in connection with the meeting of the Association of Southern Agricultural Workers, in order to canvass the present status of scientific knowledge and agricultural practice with regard to this nematode and to consider what steps might be taken by the workers themselves to insure better progress in solving the problem in its various aspects. To the Committee on Root-and-Stem Diseases of the Tobacco Disease Council, with Dr. R. F. Poole as chairman, was assigned the responsibility of arranging for the conference program and sending invitations to workers who might be interested. Dr. Wingard as chairman of the Council also assisted by communicating with directors of experiment stations and with officials of the U. S. Department of Agriculture. That the root-knot nematode problem is viewed as of serious importance to southern agriculture was indicated by the responses received and by the unexpectedly large and representative attendance.

The program, starting Tuesday afternoon, February 2, in the Andrew Jackson Hotel, was continued in the evening and concluded by a session Wednesday morning. It included informal discussions of the root-knot nematode, its life history, response to environmental factors, hosts, means of dissemination, experimental methods, and its control by chemical means, rotation systems and other cultural practices, resistant plants, hot-water treatments, etc., with reviews of recent research presented by the investigators.

Throughout the course of the program there was free and energetic discussion. The need was brought out for much additional work in many directions. Before adjournment the question of how to promote more effective attack on the root-knot nematode problem in the future came up for general consideration and led to a few definite decisions, as follows:

DECISIONS OF THE CONFERENCE. 1. The Proceedings. By general consent it was agreed that the proceedings of the present conference should be prepared, mimeographed, and sent not only to all present but to all others known to be interested, including the directors of experiment stations in the root-knot region.

2. List of Investigators on the Root-Knot Nematode. It was agreed that a mimeographed list of persons now working on the root-knot nematode, indicating the type of investigation in which each is engaged, would be of great value.

3. Future Conferences. It was unanimously voted that occasional conferences of workers on root-knot nematode problems would be desirable.

4. Organizing Committee. On nomination of a special committee appointed for the purpose (Poole, Barre, Weber, Armstrong, Wingard, and Miles) the Conference elected the following as a permanent committee to work out future plans:

Vice-Director H. Harold Hume, Florida Agric. Experiment Station, Gainesville, Florida, Chairman.

Director H. P. Stuckey, Georgia Experiment Station, Experiment, Georgia.

Dr. G. Steiner, Head, Division of Nematology, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

Dr. C. L. Isbell, Horticulturist, Alabama Experiment Station, Auburn, Alabama.

Dr. R. F. Poole, Plant Pathologist, North Carolina Experiment Station, Raleigh, North Carolina.

Dr. E. E. Clayton, Plant Pathologist, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

The Chairmen of the Tobacco Disease Council and Cotton Disease Council, respectively, were declared ex officio members of the committee.

These men are:

Dr. S. A. Wingard, Plant Pathologist, Virginia Experiment Station, Blacksburg, Virginia.

Dr. G. M. Armstrong, Plant Pathologist, South Carolina Experiment Station, Clemson, South Carolina.

DIGEST OF THE CONFERENCE PROGRAM

GENERAL FACTS ABOUT THE ROOT-KNOT NEMATODE, Heterodera marioni. Dr. G. Steiner. After outlining the organization of the Division of Nematology in the U. S. Department of Agriculture, with its main office in Washington and field headquarters at Salt Lake City, Utah, Sumner, Washington, and Tifton, Georgia, and with cooperative relations with several other divisions of the Department, Dr. Steiner discussed general facts about the root-knot nematode. It is clearly distinguishable from other nematodes by the pear-shaped adult female and by characteristics of the larval stages. It is able to distinguish host plants by means of a chemical sense organ at the anterior end. The glands in the esophagus produce a substance which is injected through the spear or stylet of the nematode and induces abnormal development of the plant tissues, which are so transformed as to interfere with normal processes in the plant and so cause far more damage than would the mere extraction of nourishment.

The life history was sketched. The larvae, hatched from egg masses, enter the root tips by forcing their way between the epidermal cells and migrating between the cells of the parenchyma, with little or no destruction of cells, thus affording little opportunity for other parasites to enter the root at this time. The head of the larva penetrates the central cylinder, where "giant" cells are formed around its mouth, apparently by the dissolution of some cell walls. From these giant cells the nema now begins to ingest nourishment and swells rapidly. Under adverse conditions, some larvae develop into males and swelling ceases. Normally, however, larvae become females and continue to enlarge until egg production begins. The egg masses may remain within the tissues of the root or they may protrude by rupture of its surface.

The parasite affects the host in three ways:

(1) Directly by taking food; damage considered small.
(2) Indirectly by producing disturbance in root tissues and consequently in vital functions. This is considered its principal damage, and was therefore broadly discussed and demonstration material was presented.
(3) Indirectly by preparing the host for other diseases.
    (a) Through weakening of the host.
    (b) Through production of open lesions.

No method of satisfactory therapeutic treatment applied to the host plant has ever been devised for eliminating the nematode from its tissues, except the hot-water treatment which is applied mainly to valuable propagating stock. Control measures must therefore concentrate action on the larvae and eggs free in the soil or remaining in the roots of harvested crops.

The root-knot nematode is distributed throughout the tropics and subtropics, through much of the temperate zone, and in greenhouses everywhere. In the United States this nematode occurs throughout the south and as far north as New Hampshire, New York, northern Michigan, and Washington State. It was prevalent in Florida in the 1860's. Papers by Neal and Atkinson treating this nematode were published in 1889. The egg can survive very low temperatures, but the period of optimum temperature for development is probably too short in the north for more than one generation a year. In the south, however, 8 to 10 generations or more may be produced in a year. It is our conception that the eggs do not require fertilization by a male.

Soil texture will not control nematodes, but a sandy soil is more favorable for them than a clay soil. There is apparently no relation between the nematode and soil reaction, except that coal ashes mixed with soil are said to give control. Further studies are needed to determine the maximum span of life of eggs in the soil. Eggs apparently survive in flooded soil for a year but absolute dryness kills them. However, viable eggs were found in roots of tuberous begonias and kept dry 18 months.

Miss Jocelyn Tyler quoted Godfrey as saying that the nematode will develop under any moisture conditions under which the host plants will live. She also has conducted experiments with nematodes developing in roots submerged in culture solutions. She found that larvae may live for several months in aqueous solutions containing a few sand grains. Egg masses were killed by drying in one afternoon in the laboratory, but thorough drying is difficult in the soil.

HOST PLANTS. Miss Edna M. Buhrer presented an analysis of the root-knot host list.

I. Status of list to date.
   A. 1155 species (published and unpublished) recorded in the Division of Nematology.
   B. Variation of susceptibility.
      1. Ambiguity in various reported hosts (depending on soil, climate, length of time exposed to infestation, efficiency of methods, etc.).

2. Examples: Tomato - heavily infested.
Corn, peanut, onion - variously reported as infested or not.
Grasses, Crotalaria juncea - seldom infested.

II. By classification.
A. Cryptogams (fungi and algae, bryophytes, ferns) - no hosts.
B. Phanerogams or seed plants.
1. Gymnospermae (3 of the 4 families represented on list: Cycadaceae, Ginkgoaceae, Pinaceae.)
2. Angiospermae
a. Monocotyledoneae)
b. Dicotyledoneae) both well represented on list.

III. Analysis of Phanerogams.
A. By number and families: 118 of a possible 280 families infested - 42 percent.
B. From evolutionary viewpoint, no conclusions can be drawn.
C. Quantitatively per family - by percentage ranging from 0.07 to 100 percent of the species of each family represented on host list.

IV. Discussion of families not known to be attacked (by number, 162).
A. Are they omitted by reason of rare or restricted occurrence, and therefore unobserved as hosts?
B. Are they not infested by reason of their habitat? Examples:
1. Parasitic plants: Loranthaceae (including mistletoe)
Rafflesiaceae (parasitic herbs)
Orobanchaceae (parasitic herbs)
2. Aquatic plants: Potamogetonaceae
Naiadaceae (gen. Najas)
Alismaceae
Hydrocharitaceae
Lemnaceae (free-swimming, perennial, water plants)
Nymphaeaceae (including waterlilies)
Ceratophyllaceae
C. Families not reported infested for unknown reasons, of importance for investigation as rotation possibilities. Examples:
Tamaricaceae (genus Tamarix)
Cistaceae (genus Helianthemum, sunrose, as ornamental)
Elaeagnaceae (genus Hippophaë, as ornamental).
Cornaceae (genus Cornus, dogwood, as ornamental)
Aquifoliaceae (genus Ilex, holly, as ornamental)
Celastraceae (genera Celastrus, bittersweet, and Euonymus, as ornamental)

Hippocastanaceae (genus Aesculus, horsechestnut, as ornamental)
Casuarinaceae (genus Casuarina, as ornamental)
Pandanaceae
Ericaceae (including rhododendron, azalea, as ornamentals)

Crotalaria spectabilis has never been reported as infested although other species of Crotalaria have been found attacked.

For more detailed information on host plants refer to The Plant Disease Reporter, vol. 17, no. 7, June 15, 1933, or correspond with Miss Buhrer. A revised host list is being prepared and suggestions were requested as to the form for rendering it most useful. It was suggested that annotations in the host list indicating something as to relative susceptibility or resistance, where this has been well established or is strongly supported by evidence, would be useful.

The question was raised as to why there were such apparent fluctuations in susceptibility. It was Mr. Taylor's suggestion that the condition of the soil at the time of testing might explain this, that if the soil were too dry the nematodes would go to greater depths. Even on tobacco at Tifton, Georgia, considerable variation has been noticed in the infestation on different plots.

Dr. Taubenhaus inquired about the depth of nematode infestation in soil, and referred to experiments on the control of root rot, in which he had soaked the soil to a depth of two feet with 10 percent sulfuric acid poured into crowbar holes four inches apart.

Dr. Steiner mentioned that most plant nematodes develop strains which prefer particular host species, the hosts inhabited by the parents being preferred by the offspring. In this respect the root-knot nematode is the least developed but there are some indications of specialization. For example, cases have been reported where it was difficult to transfer root-knot nematodes from squash to tomatoes and, again, from tomatoes to lettuce. He reported that in some localities peanuts and corn were not attacked at all, in others, however, quite heavily. Evidence of the formation of geographic strains is lacking.

As to the most susceptible hosts, Miss Buhrer stated that tomato is considered one of the worst, while others indicated squash or tobacco.

Dr. Steiner reported that it was the intention of his Division eventually to publish a technical bulletin which would summarize all the established facts regarding the root-knot nematode. Such a bulletin could not be published at once, however, due to the pressure of other activities.

ARTIFICIAL CULTURE METHODS. Miss Tyler described the experiments of Dr. Christie, of the Division of Nematology, in which he inoculated with individual nematodes the seedling roots of tomato, observing the responses of the host from day to day with results which have enabled him to give a clear picture of the process of gall formation. She reported her method of cultivating nematodes aseptically in tomato seedlings growing in agar or in Pfeffer's solution. An egg mass might be used for the initial infestation, but after one generation in culture it was relatively easy to obtain infestations with single nematodes. This method has been applied to studies of temperature and of sex ratios, and might be usefull for other hife history studies. Dr. Poole mentioned that Dr. Shaw has found sweet potatoes an excellent source of nematodes, uncontaminated because of their location up to one-half inch under the skin.

PARASITES AND OTHER ENEMIES OF THE ROOT-KNOT NEMATODE. Dr. G. Steiner. Free-living nematodes are common in the soil. Some of them are predatory and feed on soil animals, perhaps on rotifers or on small earthworms, and even on other nematodes, as do, for example, the mononchs, a widely distributed group monographed by Cobb. Dr. Steiner has observed a specimen of Mononchus papillatus which killed as many as 83 root-knot nematode larvae in a single day. In Indio, California, an attempt was made to colonize mononchs in date-palm plantings heavily attacked by root-knot, but it proved difficult to keep track of these mononchs, and no artificial culture methods are at present known for propagating them on a large scale. Linford and also McBeth have seen certain aphelenchoides feeding on other nematodes. The tripylas and diplogasters also have predatory members, and various dorylaims feed on soil animals. Only the free-living, soil phase of the root-knot nematode is exposed to these attacks. However, rhabditids and diplogasters are possible feeders on the egg masses in decaying roots. There is a chance for important fundamental work along this line.

Zopf, Drechsler, Sherbakoff, and Linford have all reported fungi which trap and kill nematodes. Until recently these nematode-catching fungi had been found in association with free-living nematodes only, but in a recent issue of Science Linford presents evidence that they are of real significance in the control of root-knot nematodes in Hawaiian soil. Attention is called to the danger of misinterpreting the results of tests in which large amounts of vegetable matter are added to the soil, since the decay of this material may produce substances which temporarily inhibit the hatching of the nematode eggs. Linford, however, found an increase in the number of nematode-attacking fungi where plant material was incorporated in the soil, and a subsequent reduction in root-knot-nematode activity as measured by test plants. Sporozoa, parasites belonging to the Protozoa, in some instances have been found greatly to reduce free-living nematodes, but have not yet been reported as parasitizing the root-knot nematode.

Other soil organisms may feed on the root-knot nematode. Carnivorous mites may attack sessile females and egg masses. Earthworms may swallow them along with root parts, although it is possible that in this case the eggs might pass through the alimentary tract uninjured. Insects feeding on roots, e.g., the ant, Solenopsis xyloni (now S. germinata var. xyloni), reported by Neal, may also consume egg masses.

RESPONSES TO ENVIRONMENT. Mr. A. L. Taylor reviewed the literature on all phases of this subject.

Temperature: Root-knot infestations have survived in places where the ground froze to a depth of three feet, and again where the air temperature reached -30° F.

Larvae were killed in experiments by Hoshino and Godfrey in less than 1 minute at 48°, in less than 1 hour at 41°, and in 2-1/4 hours at 40° C. Eggs in egg masses were killed in less than 1 minute at 52°, in less than 1 hour at 44°, and in 4-1/2 days at 40° C. These data are valuable guides in heating soil and in treating roots with hot water.

Miss Tyler obtained root penetration by larvae at temperatures from 12° to 35° C., and egg laying from 14.5° to 31.5°. The life cycle from larva to larva occupied 25 days at the optimum temperature, 27°, and 87 days at 16.5° C.

Some crops will grow at this latter temperature and could be raised in infested soil without serious damage. Possibly other crops might do well at a soil temperature of 100° F., which is too high for continued nematode activity. The soil temperature at Tifton, Georgia, averaged below 62° F. during four months of the winter of 1932-33. From May through September it was near the optimum for nematode activity. Under good conditions we should expect eight or even ten generations of nematodes a year in Tifton. Somewhere in Florida we would find the northern limit of continuous activity, with at least twelve generations a year possible. The potential increase of population in ten generations is enormous, even considering that only a small percentage of the 300 to 600 eggs produced by one female may hatch and the worms develop and reproduce. Farther north the period of inactivity would increase, until in the northern United States probably not more than one generation would develop each year.

Moisture: Godfrey and Hoshino tested the survival of this nematode at different degrees of dryness. One hundred percent humidity is necessary for survival. At 90 percent humidity larvae were killed in 30 minutes, eggs in egg masses were killed in 9 hours, but 75 percent of the eggs in root galls survived 20 days in this atmosphere. At 50 percent humidity larvae were killed in 4 minutes, egg masses in 2-1/2 hours, eggs in galls in 2 days.

However, it is impossible to reduce humidity below 100 percent in the soil interspaces on a large scale. Infested roots dried in the sun for a week or two should be free of this nematode. Roots should always be plowed out of the ground after harvest and allowed to dry before being turned under. Plants such as cotton left standing in the field after picking will produce another generation or two of nematodes to infest the soil.

Brown, in California, obtained a great reduction of nematodes after 1 year of continuous flooding. Free larvae were not found after 4 months but the infestation remained, probably as viable eggs, somewhere between 12 and 23 months. In parts of Florida, where the fields are tiled for drainage and subirrigation, and where artesian water is obtainable, farmers control root-knot by flooding their soil for several weeks at a time. Some believe that alternate flooding and drying of 2 or 3 weeks each is more effective, but there are no experimental data. The ground is cultivated during the dry intervals to promote hatching of eggs. The larvae are stirred to activity by the excess water and soon exhaust their stored food supply. Without available host plants they die of starvation.

Physical and chemical factors: Bessey found that new roots of infested plants transplanted to clay soil remained free of root-knot, and other susceptible plants in the same pot were not attacked. This effect is generally thought to be due to the mechanical difficulty the larvae have in making their way among the finely divided soil particles.

There is possibly a slight reduction in infestation at pH values above 7.6, according to Godfrey and Hagan, but no other differences were found though soils were tested through a pH range from 3.5 to 8.5. Anagnostopoulos on the other hand states that in the soil of the Laboratory of Horticulture in Athens, Greece, a high content of lime and a pH of 7.5 and above is responsible for the absence there of the root-knot nematode.

Food supply: The root-knot nematode is an obligate parasite. Larvae scattered through the soil must come within a few inches of a root tip, or else spend their lives wandering aimlessly through the soil and finally die of starvation.

Just how far a nematode can scent the secretions from a root tip in the soil water is not known, and probably varies with the plant species and with the movement of the soil water. It seems possible also that the physiological nature of the root would affect the nematode, in length of life cycle, and in number and viability of eggs produced. Godfrey and Oliveira found a period of 35 days from inoculation to egg-laying in pineapple roots, compared with 19 days in cowpea roots under identical conditions. There are tentative suggestions in the literature to the effect that nematode resistance depends on the physical nature of the root, but there is little real evidence on this subject.

METHODS OF DETERMINING AND MEASURING INFESTATIONS. Miss Tyler discussed the common method of measuring soil infestation by means of indicator plants, used in cases where it is important to know whether or not a certain soil is infested, and also to determine the results of soil treatments. The roots of crop plants and weeds may give valuable information in the field, but the absence of galls is not always a dependable indication, particularly in plants with fleshy roots. Field samples may be tested in greenhouse pots. Standard conditions for a pot test require a highly susceptible host plant with a rapidly growing, spreading root system and definite gall formation not confused by legume nodules, grown for thirty days, or one generation, under optimum conditions of soil texture, temperature, and moisture, without contamination by nematodes from other sources. To certify land as entirely clean requires repeated, careful, and prolonged tests.

Statistical analyses of field material have been proposed. The percentage of plants infested may give a good indication of the situation in some cases, but not in others, as when there is a low population well distributed through the field.

A question was raised on the survival of nematodes in fallow land, whether for one or two years, and whether in the egg or larval stage. More information is needed on this point.

Dr. Poole reported heavy infestation of tobacco by the root-knot nematode in Cecil clay soil. The collecting of information on the actual distribution of root-knot in various types of clay soil was held desirable.

MEANS OF DISSEMINATION. Dr. G. Steiner. The active migration of larvae in soil is restricted to distances of only a few feet, depending on the character of the soil and other environmental factors. Dissemination over long distances is always passive, mostly through the agency of man. Dissemination in nursery stock is extensive. Seedling plants from the south are shipped in quantities to the north and may carry infestation. Corms, bulbs, tubers, rooted cuttings, and plants of any kind with infested roots are disseminators. Seed potatoes have undoubtedly been the means by which the root-knot nematode invaded important potato areas in Oregon, Washington, Idaho, and Long Island. Some dissemination takes place through the distribution of marketable products such as carrots, salsify, celeriac, Irish potatoes, sweet potatoes, even spinach. Irrigation water run over infested fields and turned back into main ditches may carry nematodes for long distances. Local short-distance dissemination is possible by means of tools and cultivation implements. In hot climates such dissemination is perhaps restricted by rapid drying. Horses and men may carry the nematodes on their feet with adhering soil and parts of infested roots. Cleaner working methods are recommended to improve this situation. Sanitation is especially important in greenhouses for pots, potting bench, etc. Seeds, unless they have come in contact with soil, are not carriers. The wind may, however, carry incompletely dried plant roots with egg masses.

RELATION TO TEMPERATURES IN FLORIDA. Dr. G. R. Townsend described experiments conducted at the Everglades Experiment Station on the rate of development of the nematode in the field as affected by temperature. Bountiful beans were grown in reclaimed peat soil inoculated with galled okra roots. Soil temperatures 3 and 6 inches deep were recorded by thermographs. The length of time required for development from larvae in soil through molting to laying and hatching of eggs (table 1) was determined by frequent dissection of roots for each of ten separate generations, at different seasons during 1934, 1935, and 1936.

Results were analyzed by methods originally used by Miss Tyler. The rate-of-development curve (Fig. 1) shows a base temperature at 14.75° C. This is a mean, not the absolute minimum. By using 12° C. (54° F.) as a base temperature, and calculating hour-Centigrade-degree units above this base, as shown in table 2, the amount of development of the nematodes in a given period could be estimated with reasonable accuracy, and form the basis for the more intelligent application of control measures. An increase of 10° C. in the minimum temperature caused a decrease of at least one-half in the length of life cycle (table 1). At continuous optimum temperatures, sixteen generations a year might be possible. In southern Florida ten or twelve generations might develop in a year if fresh host plants were constantly available.

While rather consistent results were obtained in these studies, they should not be assumed to apply directly to conditions in which other host plants and soil types were involved or where factors not present in this experiment might exert an influence.

TABLE 1. Effect of soil temperature on generation-time of H. marioni on beans.

Generation	Generation-time days	Mean temp. °C.
1	22	27.38
2	36	23.47
3	64	19.54
4	34	25.60
5	24	29.48
6	30	27.08
7	39	22.74
8	77	17.56
9	35	24.29
10	24	26.19

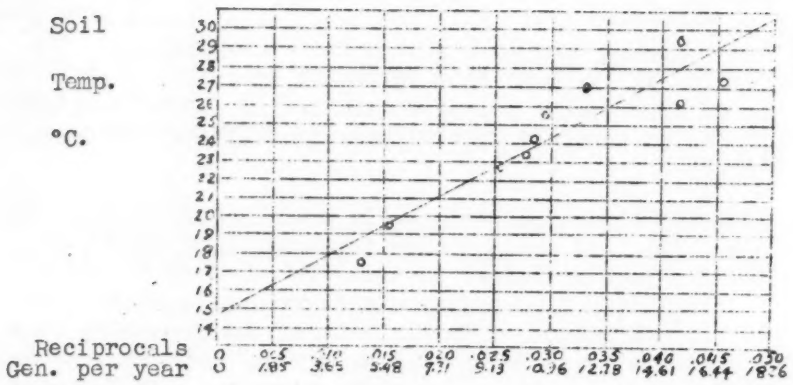


Fig. 1. Rate of development of H. marioni on beans as influenced by soil temperature.

TABLE 2. Hour-Centrigrade units above 12° and the stage of development of H. marioni on beans.

Generation	Number of units from free larvae to: Gall formation	Molting	Egg laying	Hatching
1	1465	3269	6731	8123
2	1272	4201	8352	9911
3	2668	6010	8730	11576
4	2951	----	8920	11101
5	1665	5467	8446	10065
6	6178	----	9293	10864
7	1483	3865	6191	10056
8	2275	----	8202	10276
9	2230	----	9384	10324
10	1492	----	6827	8177
Means	2368	4564	8108	10048
Standard deviation of means	436	456	339	339

Assuming that 100 larvae hatch from one female, the following generation theoretically would be 100 x 100 and so on. The rapid increase possible at optimum temperatures indicates why nematodes "come back" unless control measures are constantly enforced. Experiments on control with chlorpicrin were conducted by Neller in Florida, but except for seed beds this treatment was unprofitable because reinfestation is so rapid.

A discussion of factors responsible for inhibiting indefinite multiplication of the nematodes brought out the suggestions that the food supply and various enemies of the nematodes must both be involved, although what the parasites or controlling organisms may be is as yet unknown for the Florida situation. Dr. Steiner mentioned that, in the case of Heterodera schachtii in sugar beets, the heavy infestation of a root delays hatching of the eggs. A possible explanation is that heavy infestation stops the growth of root tips and thus stops the root-tip secretion which is supposed to stimulate hatching. It was asked whether in southern warm soils where the nematodes increase so rapidly, parasites would not attack them more abundantly, or the nematodes by their numbers create conditions unfavorable to their own growth. Dr. Steiner remarked that on these points no exact data were available, and cited the unexplained fluctuation in the tobacco-rotation plots at Tifton as indicating the presence of possible controlling factors like parasites. Under optimal conditions the larvae could probably stay alive three or four months in the soil without access to host plants.

EXPERIMENTS ON NEMATODE CONTROL IN FLORIDA WITH FERTILIZERS AND CHEMICALS, AND BY CULTURAL METHODS. Prof. J. R. Watson. The most economical control for root-knot on Florida truck farms is to grow an immune cover crop, such as Crotalaria spectabilis, during the long rainy summer. Careful cultivation eliminates weed host plants and aerates the soil enough to force all eggs to hatch.

Permanent seed beds demand more prompt treatment. Rotations cannot be practiced because of permanent irrigation systems. In such cases we use sodium cyanide extensively, following the procedure of Dr. Woodworth of the California Station. We dissolve the sodium cyanide in water, apply it as evenly as possible to the surface of the soil, then turn on the irrigation water, usually overhead sprinklers, until the solution is carried down to the depth of a foot or so. Ammonium sulfate in solution is applied immediately after this, certainly the same day, and washed down with a little irrigation water. The amount of ammonium sulfate used is always 50 percent more than the amount of sodium cyanide. The reaction between these two chemicals releases hydrocyanic-acid gas in the soil. The soil must be covered immediately to retain this gas. Balloon cloth is one of the best covers, but building paper, canvas, paraffin-impregnated cloth, or even newspapers have answered the purpose.

Because nematodes are so generally distributed and reinfestation is so prompt, we aim only to reduce the nematode population to a point where profitable crops can be produced during one trucking season. In the ancient sand

dunes on the lower east coast of Florida, used for growing pineapples, a dosage as low as 300 pounds of sodium cyanide and 450 pounds of ammonium sulfate per acre is effective. On Norfolk sandy loams more commonly used for trucking, such as most of the soils about Gainesville, 600 pounds of sodium cyanide and 900 pounds of ammonium sulfate usually give commercial control. Materials alone for this dosage cost over $100 per acre. To get complete eradication it is necessary on this type of soil to use 1,000 or 1,200 pounds of sodium cyanide and, as always, 50 percent more of the ammonium sulfate. It takes an even higher dosage to kill Bermuda grass, but soil insects and all small weed seeds are killed by an ordinary fumigation. The soil may be planted within a week or ten days after treatment. We have treated an area as large as two acres in a celery farm.

The response of plants raised on these treated beds is greater than would be accounted for by the excess of ammonium sulfate left in the soil. It seems as if the action of the gas on the soil colloids must be a contributing factor in the surprising fertility of the treated soils. Ammonium sulfate alone helped greatly, probably by supplying the infested plants with an abundant supply of nitrogen, but we did not find sodium cyanide alone satisfactory. Some truckers consider that the fertilizer value of the materials is worth the cost, and they get the nematode control for nothing. We have found this method cheaper than attempting to steam the soil or treat it with hot water, unless the seed bed is permanently piped and a source of steam readily available.

We tried the less expensive calcium cyanide, but we had to use twice the amount to get the same degree of control without the fertilizer value. However, the soil moisture was sufficient to liberate the gas without watering.

Cyanamid gives a less expensive treatment and is now used extensively on truck crops on acreages. Applied in the dry form it seems to have almost no power of penetration, so it must be very thoroughly mixed with the soil. One-half of the dosage, namely 500 pounds per acre, is added to the top of the soil, which is then thoroughly disked. The land is then deeply plowed and the other 500 pounds added to the top of the plowed soil, which is again thoroughly disked. This procedure has usually given us fair commercial control of nematodes, though in some cases we have also added cyanamid to the bottom of the furrows, either by hand or by means of a distributor fastened to the plow. It is not safe to plant the land within three or four weeks after application of the cyanamid, depending somewhat on the rainfall during this period. In fact, an application of old, caked cyanamid once, during the war, sterilized an acre so thoroughly that the owner could raise nothing on the land for a year.

We found that an application of sulfur as low as 300 pounds per acre decidedly reduced the number of nematodes in the soil, but never could we get complete eradication, though we went as high as two tons per acre. Even 500 pounds per acre made the soil too acid.

Perennial plants and trees present a particularly difficult problem in nematode control. Several years ago, in cooperation with the Horticulturist of the L. and N. Railroad, we tried the effect of calcium cyanide on peach trees. An application of half a ton per acre injured the trees but no injurious effects were noticed with dosages of 750 pounds or less, nor from half a ton if given in two applications three or four months apart. Trees given from 500 to 750 pounds showed a marked improvement in color and made better growth than the checks, but the results hardly seemed to justify the expense.

After two years the trees were dug up. The trees which had received 500 or more pounds of cyanamid per acre per year showed an appreciably smaller number of galls on their roots.

The question was raised as to whether the improvements in plants treated with cyanamid might not be due to mere fertilizer effect. However, comparable amounts of nitrogen were employed on check plots and it was found that the sodium cyanide-ammonium sulfate combination gave distincely improved control of the nematode. It did not have any permanent effect on nut grass. The question arose as to whether nut grass, Cyperus rotundus, is a host of the root-knot nematode. Dr. Poole reported having seen nematode galls on it.

Dr. Poole reported promising results with cyanamid, especially on poor soil. He obtained great reduction of nematodes in 1935 with 1,000 pounds per acre and intends to test 2,000 pounds per acre.

Prof. Hume emphasized the importance of Prof. Watson's work with Crotalaria spectabilis. He cited the work at the North Florida station, where in breeding tobacco for resistance to black shank it became necessary to repeat tobacco on the same soil year after year. In 1934 nematodes became so abundant that the crop could not be grown there. In July the ground was planted to Crotalaria spectabilis in rows and no other plant was allowed to grow: similarly subsequent years. Since that time there has been no trouble from nematodes with the experiments on these plots. The soil is of a clayey type with sandy loam on top, there being not enough clay to interfere with the nematodes.

CHEMICAL CONTROL STUDIES. Mr. A. L. Taylor. The ideal chemical was defined as one effective against all stages of the nematode but harmless to the plants, easily obtainable and cheap, not harmful to man or animals, and leaving no harmful residues in the soil. No material now known satisfies all these desired conditions.

Chlorpicrin, applied under climatic and other conditions prevalent at Tifton, Georgia, during the season of 1936, at 200 or 400 pounds per acre ($1.00 per pound), was found 100 percent effective as compared with the

controls; at 100 pounds, 93.5 percent effective; at 50 pounds, 82.3 percent effective. Carbon disulfide at 1,000 and 2,000 pounds (10 cents per pound) was 97.8 percent effective; at 500 pounds, 88.7 percent; at 250 pounds, 36.2 percent. Cyanamid applied in furrows up to 2,000 pounds per acre gave no observable control. (Prof. Watson called attention to his experience indicating the need for thorough mixing of this chemical with the soil). Ammonium thiocyanate (18 cents per pound) applied dry to damp soil up to 1,600 pounds per acre gave no control. However, when dissolved in water, even 800 pounds per acre made it impossible to grow any plants throughout the rest of the season.

Carbon disulfide, 68 percent emulsion, mixed with water and applied by hose to the soil at the rate of one gallon to 200 square feet had no effect, but at the rate of 1 gallon to 100 square feet proved 96.6 percent effective and at 1 gallon to 50 square feet, 100 percent effective. Formaldehyde (37 percent) up to 1,088 gallons per acre ($1.00 per gallon) was not effective. Prof. Hume remarked that Dr. Neller had designed an applicator for chlorpicrin and carbon disulfide, which are poisonous materials and cannot be used where perennials are involved.

Dr. Plakidas reported an experiment with cyanamid applied by Prof. Watson's method in very sandy soil in July, at the rate of 1,200 pounds per acre. Cucumbers planted five weeks later on the treated soil made a good start and produced a large crop. Their roots showed 50 percent fewer galls than the checks.

Miss Tyler pointed out the discrepancies in the results of various tests and suggested that the soil type might account for some differences, since clay absorbs and holds cyanide and other materials to an extravagant extent. She called attention to the excessive rate at which carbon disulfide emulsion was used in Mr. Taylor's experiment, as compared with his dosages of undiluted carbon disulfide. Another extravagant form of carbon disulfide is potassium xanthate. Formaldehyde in dust form is similarly dissipated. Cyanamid is primarily a fertilizer rather than a fumigant.

Chlorpicrin is more effective than any chemical that was used for nematode control ten years ago. There is an important field for study on the application of this sort of material with subsoil machines, and on special covers for confining volatile fumigants. There was some discussion on the value of 90 percent control, if 100 percent control in the field by any practicable method should prove too much to hope for.

GENERAL DISCUSSION ON CROP ROTATION WITH RESISTANT PLANTS. Prof. Watson, reporting on tests for resistance at Gainesville, Florida, said that only one case of root-knot infestation had been found on Crotalaria striata and none on other species of Crotalaria.

The problem of nematodes on tree roots was discussed. Since nematodes will come in from neighboring land, this can be solved only by the development of resistant stocks. However, Mr. Barss suggested the possibility of developing populations of soil organisms in orchards antibiotic to nematodes - a method used with some apparent success against Texas root rot in Arizona. Dr. Steiner suggested that if the perennial were started with clean roots, any nematodes subsequently introduced might be controlled by a very attractive trap crop, requiring, however, the closest attention.

Mr. H. W. Barre brought up the question of studying bare fallow closely enough to find the conditions under which a soil could be freed from infestation, and to find the minimum time. Mr. C. J. King reported that at Sacaton, Arizona, after two years of fallow and summer tillage of nematode-infested land only a few islands of galled plants occurred in a block of susceptible cotton. In three years the elimination of the nematodes appeared complete. This treatment had so improved the soil as to double the crop. The soil was turned one foot deep three times during the summer, and between rains a disk harrow was used. The soil temperatures averaged 80 to 86° F., and even 92° in the top six inches.

Referring to fallowing methods, Prof. Watson indicated that this method gave commercial control in four months in muck soil, but ruined the fertility of sandy soil. Dr. Townsend reported that some truckers who had been using fallow methods on muck land had gotten bad soil effects and given up the method.

Mr. King reported that ammonium carbonate, applied in large quantities, ruined the soil for one year and gave only partial control. He reported that cotton varieties differ greatly in susceptibility. Egyptian cottons (Gossypium barbadense) are badly injured by root-knot. Acala cotton (American Upland type) now replaces the former with yields of 2,000 pounds of seed cotton per acre. Other Egyptian cottons have been tried, and hybrids between Sako and American Upland cotton have been found fairly resistant. The first-generation hybrids proved very resistant and vigorous, but plants of the second generation revert to type. By rotation with grain and sorghum in the summer fair control has been obtained for subsequent crops, but it is the hope in Arizona to eradicate the nematode by fallowing methods.

DEVELOPMENT OF ROOT-KNOT-RESISTANT VARIETIES OF CROP PLANTS. Mr. K. C. Barrons. Dr. Isbell of Alabama has developed a resistant bean originating from seed collected from Alabama farmers. Two selections, Alabama No. 1 and No. 2, proved resistant for practical purposes, with only a few small galls. Desirable commercial types with resistance equal to Alabama No. 1 and No. 2 are being bred from these and will be ready for distribution in about two years.

Orton's Iron cowpea is more resistant than Brabham and Victory cowpeas, bred from Iron. A strain of Conch cowpea tested in Alabama seems almost immune

in the adult stage. Prof. Watson, however, thinks some strains may be susceptible. The resistance factor in Iron cowpea has been found dominant, but not inheritable by simple Mendelian segregation. At Alabama an effort is being made to develop resistant edible cowpeas through crossing Iron and Conch.

Hopi 155 is probably the best "butter" bean for the South to grow because of its long season of bearing and its resistance to drouth. Mr. King reported that he had collected many colored limas from the Hopi country, some much more resistant than Mackie's Hopi 155, but the trade does not want these mottled limas. Mr. Barrons quoted observations on resistance in cotton and also in tobacco and soybeans. Irish potatoes so far show no freedom from nematodes but some differences in susceptibility. Among sweet potatoes Red Jersey and other varieties show some resistance. There is a good chance for holding resistance once it is found in sweet potatoes because they are vegetatively propagated. Tufts and Day report some resistant peach, plum, cherry, and almond varieties. There is a possibility of budding or grafting susceptible species or varieties on to resistant stocks, and a single source of resistant seed is sufficient, without segregating the genetic factors. Old trees surviving in infested areas should be sought for their possible resistance.

At Alabama a search is being made for resistance in the tomato. Variations in susceptibility have been found. Perhaps by crossing two somewhat resistant varieties offspring more resistant than either parent may be obtained by transgressive segregation. To illustrate the possibilities of grafting, Mr. Barrons remarked that Dr. Isbell has grown tomatoes on roots of jimson weed (Datura stramonium). His experiment was in connection with tomato mosaic control. If, however, jimson week should prove tolerant of nematode infestation, as appears possible in spite of abundant galls, such a graft would be of more than theoretical interest.

Seedling tests for resistance now used with beans, lima beans, and cowpeas help to speed up the breeding work. By inoculating the soil in the greenhouse bench with affected tomato roots, bad infestations were obtainable twenty days after planting. The method used for classifying infestation in homozygous strains was to take a sample of ten plants from each of the different lots and rate them by inspection as to severity of attack, on a scale of from 1 to 5. Gall counts were not worth while. Good correlations were found between field and greenhouse performance in beans and cowpeas, but Hopi limas, which have adult plant resistance in the field, showed little resistance in the twenty-day greenhouse test. The question of seedling stage susceptibility in relation to adult plant resistance should be checked and tested out.

Mr. Taylor reported his experience with Iron and Brabham cowpeas at Tifton. One field of Iron was found about 50 percent infested. Brabham was found 10 to 15 percent infested. It was conceded that the Iron seed may

have been rather badly mixed and that the same was true to a lesser extent for Brabham. The Iron cowpea has been used for thirty-five years. Such crops are valueless in rotations for nematode control. Dr. Edson remarked that, unless provision is made for continuous selection, considerable variation might be expected to develop in any resistant line. Mr. Taylor reported that Mackie in California is trying to segregate resistant lines of the Iron cowpea type.

The question was raised whether there is a difference in the time of root-knot nematode attack on different hosts. Godfrey was cited as reporting a difference in the rate of development on pineapple and on cowpea, a more favorable host. Mr. Taylor reported finding a difference in time of attack by the nematode on adjacent rows of beans of different varieties.

Mr. Kime referred to his experience with cowpeas in North Carolina, where Iron and Brabham have shown more tolerance than other varieties. Nematode resistance seems to be related to Fusarium-wilt resistance. One Iron strain of a later and more vining type, picked up near Wilson, was found highly resistant to both. Dr. Poole suggested that all interested should obtain samples of this promising strain. Mr. Barrons suggested the use of artificial methods of inoculating field soil, to obtain an infestation many times greater than otherwise. Vetch planted in September is a good source of soil-infesting material in the spring, while tomatoes are excellent for a summer supply.

ELIMINATION OF ROOT-KNOT INFESTATION FROM PLANTS. Dr. Steiner. The one successful therapeutic treatment of plants so far devised is to soak the roots for a specified time in hot water maintained at a specified temperature, the standard treatment being one-half hour at 118° F. There is need for careful study on the tolerance of various tubers, corms, and bulbs, and of roots, especially nursery stock (roses, young trees, etc.). The tuberose will stand 126° F. and do better than if not treated. The fancy-leaved caladium illustrates one of the problems: only properly ripened tubers will stand the temperature necessary for controlling the nematode. Peony roots stand the treatment very well. Plants in general tolerate shorter treatments at higher temperatures better than the more extended treatments at lower temperatures.

No other therapeutic methods or nematocides have been developed for the treatment of infested plants. Occasionally trimming is resorted to for removing galls from propagating stock, or cuttings from above the soil are used to avoid infestation. The question was raised as to whether x-rays had been tried out. Dr. Steiner reported that various types of x-rays, infra-red, ultra-violet rays, etc. had been tried without any evidence of beneficial effect unless the temperature rose to the point where it affected the nematodes.

SPECIAL DISCUSSION OF NEMATODE HOSTS. Prof. H. Harold Hume. On invitation to discuss any phase of the nematode problem which he might consider helpful, Prof. Hume began his discussion by taking up the question of nematode hosts, calling attention to the fact that in the present host index we have positive records of attack but no comparable records of resistance in plants. In ornamental gardening and landscaping, it would be desirable to use root-knot resistant types of shrubs rather than susceptible types. In his experience some plants, such as Pittosporium tobira, which originally appeared tolerant, have shown injury after a period of years. All azaleas, both American and Oriental, are free from nematodes, or at least able to persist year after year where other plants succumb to nematodes. All camellias, including C. japonica and C. sasanqua, appear to be free from attack. Prof. Hume reported never having seen harmful infestation on conifers, naming the Taxaceae and the genera Pinus, Chamaecyparis, and Juniperus. He stated that he had never seen a rose that was not attacked but that he had observed much variation in the extent of damage. Madame Plantier of the China rose group, often used in the South as a stock, a very old type, was not badly affected. Marianna plums had never been seen infested by nematodes. Other plums and the Chinese group of pears had never been found affected sufficiently to be damaged in growth. The roots of the native persimmon are quite free from damage. Many of the Oriental persimmons may probably also be resistant. Of the Ligustrums, five species of which are reported as hosts, only L. quihoui has been free from attack, and is useful as an understock for other species of privet. L. ovalifolium and L. amurense are among the most susceptible hosts for white fly and also for root-knot nematode. There is a correlation in susceptibility of a species to various pests. No species of oaks have been seen affected nor has Magnolia grandiflora. Deciduous magnolia may be grafted satisfactorily upon M. grandiflora. Although the mulberry is infested it does not suffer much injury.

Prof. Hume voiced the opinion that uncontaminated natural soil is free from root-knot. Peach seedlings which are seeded in cleared virgin land may be grown for one or two years before nematodes appear, then the nurserymen must rotate. A method used to advantage for clearing heavily infested nursery land of nematodes is to plant it with pine trees set near enough together to shade the soil, keep green weeds out, and cover the ground densely with needles. Within six or seven years, possibly less, the land will be free of nematodes. In small gardens the grower can get plants well started by excavating the ground and putting in uninfested soil.

Prof. Hume described the nematode problem as something of an orphan child, more or less neglected by plant pathologists and entomologists. The heart of the problem of permanent control lies in the resistance of plants. All should watch for such resistance regardless of the value of the particular plants, since resistance found anywhere might be combined with desirable qualities.

Dr. Steiner mentioned a supposedly resistant species of gardenia. He told of a $100,000 loss to one cyclamen grower because a very few galls can prevent the blooming of this plant.

Mr. Barss asked if it would be possible to arrange for systematic testing for resistance of plant species and varieties, perhaps through co-operative effort. Dr. Poole suggested that a committee might handle this for the benefit of all.

THE ROOT-KNOT NEMATODE IN RELATION TO OTHER PLANT PARASITES. The question arose as to what other plant pathogens may be aided by nematode attack. Dr. Arndt studied sore shin of cotton in South Carolina in relation to several nematodes other than root-knot, but the results did not appear conclusive. There is some indication that fungi may, under certain circumstances, enter the lesions made by nematodes. Rhabditis is known to carry a bacterial disease in mushroom beds. Dr. Poole mentioned that the blistering of leaves of tobacco plants affected with root-knot was magnified before harvesting by the decay of the galls. Dr. Moore reported the complete destruction of ten acres of Marglobe tomatoes apparently as the result of wilt started by nematodes. Mr. Taylor asked for definite evidence that the root-knot nematode and the Fusarium wilt of cotton work together. Dr. Armstrong reported that at South Carolina one test was run in which they got more wilt in pots with the root-knot nematode than without it. The test will be repeated. Dr. Miles reported that, although no tests had been conducted at the Mississippi Station for the specific purpose, the wilt-resistant varieties did not stand up against wilt so well when infested with root-knot as they did without root-knot. Dr. Barker said that Sea Island and Pima cotton usually hold resistance to wilt but are extremely susceptible to root-knot. Dr. Weber reported some tests in Florida where wilt-resistant varieties of tomato did not appear to lose their resistance in the presence of nematodes.

Mr. Barss suggested experimenting with various chemical ions or chemical combinations that might be absorbed by plants either through roots or foliage and render the plant inhospitable to nematodes. The nature of resistance also might be studied by spraying with extracts from resistant plants. Dr. Steiner reported that in work already done arsenicals had proved very toxic to the nematodes while nicotine did not affect them.

SOME OBJECTIVES IN THE ROOT-KNOT NEMATODE SURVEY

ROOT-KNOT NEMATODE SURVEY. Dr. H. A. Edson. In general, the distribution and seriousness of the root-knot nematode are known. The need is for records which will provide information useful to research workers. Dr. Edson presented three different outlines for data cards, prepared by Mr. Paul R. Miller of the Federal Plant Disease Survey. First, an outline for a general

survey of root-knot and other nematodes; second, an outline for the root-knot nematode alone; and third, a simplified system of records on a smaller card, providing space on the back for any specific information of an ecological nature which might be useful in explaining the behavior of the disease.

Mr. Barss suggested collecting the authoritative information now available in the different states on the distribution of the nematode and the soil types and crops on which it is known authentically to occur, and sending this information to the Plant Disease Survey as a foundation on which to build a more complete picture as the card-system records are brought in from year to year. Dr. Armstrong insisted that there was indeed need for more study in the different states and Dr. Edson reported that the Plant Disease Survey had no information of real value as to the actual distribution of the root-knot nematode within the different states. Dr. Miles stated that there were records collected since 1920 by the State Plant Board of Mississippi, which he would try to get for the benefit of the nematode survey and for possible additions to the host list. Mr. King reported that the Soil Conservation Service has the opportunity to collect information on degrees of susceptibility of different types of plants in its nurseries. Dr. Winters reported that the North Carolina station is making a map to show the distribution of the root-knot nematode in the State. Dr. Edson reported that the Plant Disease Survey was in a position to reproduce such maps and would like to have the North Carolina map when completed.

Mr. Barrons stated that there would be wide use among plant breeders and others for a list of resistant species in all types of crops, with records on the degree of susceptibility of varieties within susceptible species.

SUGGESTED LINES FOR INVESTIGATION. Prof. Hume formulated two objectives for the group: (1) To define the place that complete eradication may play under particular circumstances, as distinguished from partial control under open field conditions in the South where eradication is not an important objective, since any land there will become infested in 2 years of ordinary handling; (2) to collect more definite information on tolerance in plants, a quality which deserves more respect.

Dr. Weber pointed out that in collecting information on variations in resistance the records should be so standardized as to permit proper interpretation. Dr. Taubenhaus argued for standard methods of inoculation. Mr. Barss recommended that a competent committee work on the question of how to manage tests and surveys so that the data on severity or susceptibility might be recorded on a standard basis. It was asked whether the Plant Disease Survey might not collect information on relative resistance or susceptibility of different host plants, and Dr. Edson indicated that he could send out an appeal for such information in the Plant Disease Reporter.

Dr. Steiner asked whether a published survey might not bring difficulties and cause trouble for states furnishing planting stock or propagating materials to other sections of the country. Nurseries, for example, with nematode-free soil would profit by information on infestations in other nurseries. Dr. Edson remarked that this was a familiar problem. The policy of not publishing anonymous statements in the Plant Disease Reporter protects both author and editor and has stimulated correspondence. Information regarding the occurrence of plant diseases may be sent to the Plant Disease Survey in confidence and not for publication. The file of unpublished information is available to research workers. There is some deliberate suppression of information due (1) to fear on the part of commercial interests and (2) to the fear of quarantine regulations, especially of state quarantines. Taking a wide view, the best course would seem to be to make all information immediately available.

Dr. Taubenhaus summarized some of the most promising and important lines for further study as follows:

1. Survey. Each worker might profitably carry out a complete survey in his own state, classifying the information on hosts affected as was done for root rot in Texas Bulletin No. 527, where the ratings were based on 20 years' experience.

2. Soil conditions affecting the root-knot nematode. Experience has shown no nematodes in the highly calcareous Houston soils in the field, though they are present in impermeable Lufkin clay. However, nematodes were found in greenhouses using the Houston soil. Here Dr. Steiner stated the belief that oxygen was needed by the root-knot nematode in the soil, but was less important to saprophytic nematodes. Dr. Taubenhaus spoke of the importance of the oxygen ratio, and also of CO_2 and other soil gasses.

3. Conditions for control experiments. Results of soil treatments vary from year to year and from state to state. It would be desirable to lay out plats with barriers to prevent reinfestation from outside. Sulfur boards and sulfur bricks make a complete barrier.

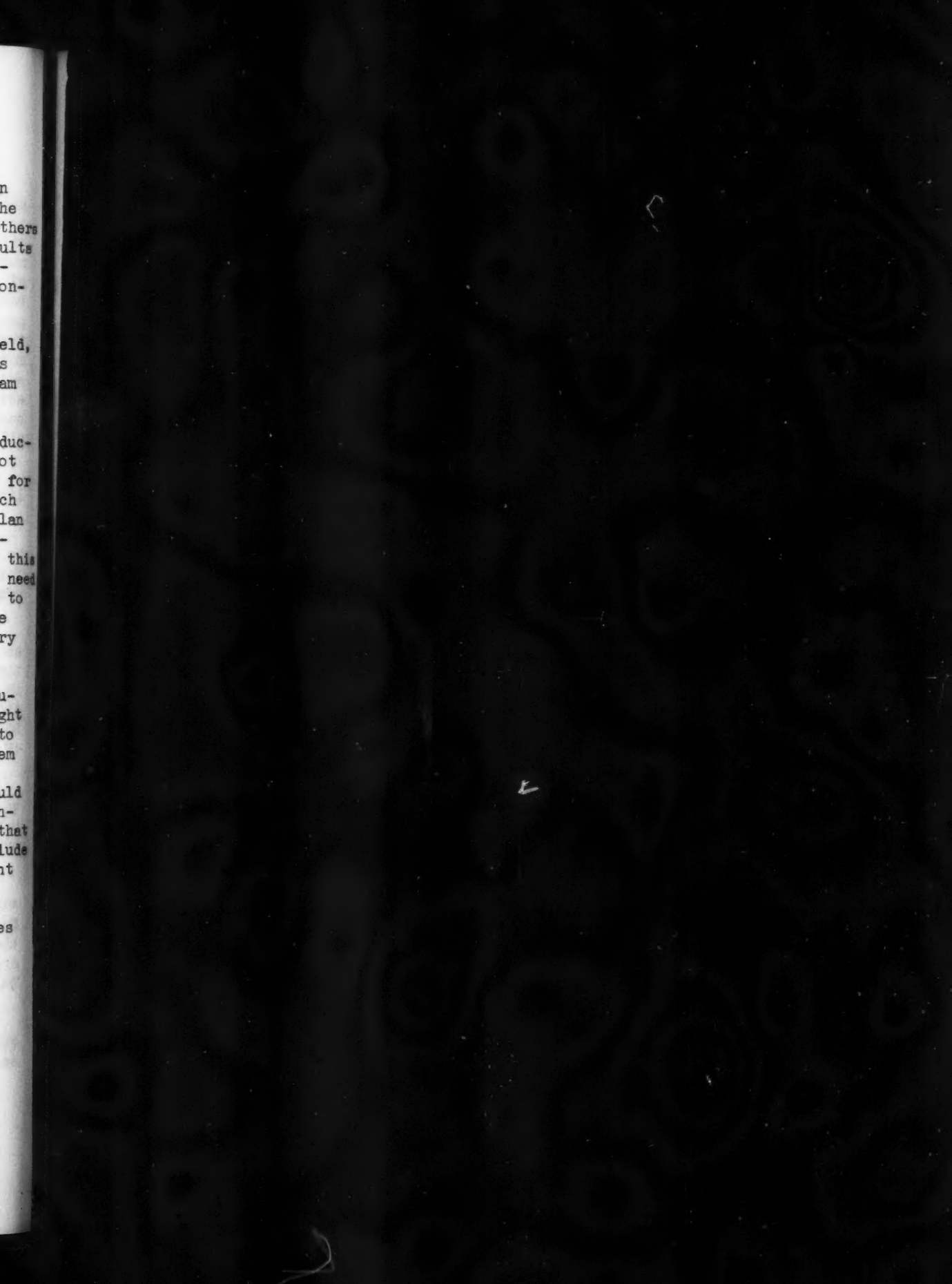
4. Soil sterilization. In Texas it is intended to continue work with sulfuric acid, using the unlimited supplies offered by the sulfur companies for experimental work. Dr. Taubenhaus stated that he would like to be given the assignment of studying soil sterilization and would like to have the cooperation of others, for whom he could arrange for the necessary supplies of sulfuric acid.

HOW TO INCREASE EFFECTIVENESS OF ATTACK ON THE PROBLEM. Mr. Barre recommended (1) the publication in mimeographed form of the information assembled at the conference for the benefit of those who could not be present;

(2) a type of organization with an informal understanding whereby certain individuals and institutions might be responsible for certain parts of the program. Those doing fundamental research would have to lead and help others to initiate work along similar lines, since it is important to check results and repeat with different crops and different conditions; (3) getting together for discussion of progress and outlook as has been done in this conference, as a most important aid to progress.

Prof. Hume suggested that a committee might project the entire field, make a list of the separate things that may be done, and then divide this work among those interested in the particular problems. Some such program would insure the relation of each phase to the whole.

The question was raised whether the Office of Foreign Plant Introduction or some other office of the U. S. Department of Agriculture might not have a nematode plot in which samples of tropical plants could be tested for their resistance to root-knot. Valuable materials might be revealed which would otherwise escape attention. It would be difficult to put such a plan into operation with all plants, since many of them are discarded, but material that shows any value should be tested. The group could well call this matter to the attention of various agencies; it could also emphasize the need for purifying Iron cowpea and breeding other forage crops for resistance to the root-knot nematode. Prof. Hume mentioned that there is much valuable plant material hidden away in our own country, and recommended exploratory work with native plants.

ORGANIZATION. A general discussion on organization to carry on future work was entered into. The complexities of the situation were brought out. In the case of the root-knot nematode, Mr. Barre called attention to the fact that persons working intensively on various phases of the problem sere scattered in such different fields as plant pathology, entomology, agronomy, horticulture, and plant breeding. It was suggested that it would require someone of experience to find a way to bring all these diverse interests together. Dr. Steiner indicated that he felt it very important that the organization should not be confined to nematologists but that it include all those interested in the root-knot problem from the standpoint of plant breeding as well as of pathology.

Decisions of the conference and organization for further activities are reported at the beginning of these proceedings.